NPOESS Orbit: Mean Local Time of Ascending Node vs. Spacecraft Time in Shadow

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Motivation

- Customers for wind mission are NASA, IPO/NPOESS, and DOD
- NPOESS orbit height is 824 km
- NPOESS mean local time of ascending node (MLTAN) (local time when crossing equator from south to north) either or 1330 (C-1, C-3) (afternoon), or 1730 (C-2, C-4) (morning) [inclination angle = 97.727 deg]
- Active remote sensors need power, hence sunlight; hence sun-synchronous orbit
- Can Doppler lidar work with any node time?
- Typical orbit software is very expensive and complicated; includes rigorous position vs. time
- We only need time in shadow
Simplified Approach in MS Excel

- Neglect earth rotation, local time, and local position
- Sun always on + y axis
- +z axis always points north
- Begin with orbit plane normal = +y axis
- SS orbit precession keeps orbit plane normal within the yz plane

- For inclination angle i, tilt orbit plane about x axis (top of orbit away from sun by i – 90 deg).
- For seasonal tilt, tilt orbit plane instead of earth, about x axis (top of orbit towards sun in summer)
- For mean local time of ascending node, tilt orbit plane about z axis (6 am = normal within yz plane)
Tilt(m) = 23.5° \cos \left[ 2\pi \left( \frac{m-17/3}{12} \right) \right]

m = number of months into year

Positive tilt is toward the sun at the north pole
Sunlight, Penumbra, and Shadow

\( x = 0 \) plane

\( D_e = \text{Earth Diameter} = 1.2756 \times 10^7 \text{ m} \)

\( R_e = D_e/2 = 6.378 \times 10^6 \text{ m} \)

\( R_s = D_s/2 = 6.96 \times 10^8 \text{ m} \)

\( D_s = \text{Sun Diameter} \)

\( 1.392 \times 10^9 \text{ m} \)

\( = 109 \times \text{earth diam.} \)

\( z_1 = \frac{-R_s - R_e}{R_{es}} y + R_e \)

\( z_2 = \frac{R_s + R_e}{R_{es}} y - R_e \)

\( z_3 = \frac{R_s - R_e}{R_{es}} y + R_e \)

\( z_4 = \frac{-R_s + R_e}{R_{es}} y - R_e \)

1. Step through time
2. Calculate \((x, 0, z)\) of normal orbit
3. Rotate orbit about \(x\) and \(z\) axes
4. Look for positions in penumbra and shadow

\( y = 0 \)

\( y = R_{es} = 1.49597870691 \times 10^{11} \text{ m} \)
824 km, +0 deg axis tilt (Sept 21)
Orbit Period = 101.2 minutes
MLT of ascending node = 12:00, 13:00, etc.
Vary MLTAN

full sun

penumbra

shadow

12 13 14 15 16 17 18 19 20 21 22 23 24
824 km, +0 deg axis tilt (Sept 21)
Orbit Period = 101.2 minutes
MLT of ascending node = 12:00, 13:00, etc.
Vary MLTAN

NPOESS MLTAN = 1330 or 1730

Minimum orbit average sunlight factor = 0.65
1330 ~ 0.665
824 km, +23.5 deg axis tilt (June 21)
Orbit Period = 101.2 minutes
MLT of ascending node = 12:00, 13:00, etc.
Vary MLTAN
824 km, +23.5 deg axis tilt (June 21)
Orbit Period = 101.2 minutes
MLT of ascending node = 12:00, 13:00, etc.
Vary MLTAN

NPOESS MLTAN = 1330 or 1730
824 km
Orbit Period = 101.2 minutes
MLT of ascending node = 1330 (1:30 pm)
Vary Month (21st)
824 km
Orbit Period = 101.2 minutes
MLT of ascending node = 1330 (1:30 pm)
Vary Month (21st)

NPOESS MLTAN = 1330 or 1730
824 km
Orbit Period = 101.2 minutes
MLT of ascending node = 1730 (5:30 pm)
Vary Month (21st)
824 km
Orbit Period = 101.2 minutes
MLT of ascending node = 1730 (5:30 pm)
Vary Month (21st)

Minimum orbit average sunlight factor = 0.87

NPOESS MLTAN = 1330 or 1730
Conclusions

• New excel tool allows quick examination of time in shadow for different orbit parameters
• Mission trades can include very important parameter of orbit average sunlight and electrical power